DEPARTMENT OF THEORETICAL PHYSICS

M.Sc. PHYSICS

Course Code	Course Title	C/E/S	Credit
	I SEMESTER		
PHY C301	Mathematical Physics	C	4
PHY C302	Electronics	C	4
PHY C303	Classical Mechanics	C	4
PHY C304	General Practical I	C	4
PHY E301	Applications of Theory of Probability and Statistics	E	3
PHY E302	Special functions and their applications	E	3
UOM S001	Soft Skill	S	2
	II SEMESTER		
PHY C305	Numerical Methods & Computer Programming	C	4
PHY C306	Electromagnetic Theory	C	4
PHY C307	Quantum Mechanics I	C	4
PHY C308	General Practical II	C	4
PHY E303	Elementary Quantum Mechanics (For students from other departments)	E	3
PHY E304	Mathematical Techniques	E	3
UOM S002	Soft Skill	S	2
UOM I001	Internship	I	2
	III SEMESTER		
PHY C309	Quantum Mechanics II	C	5
PHY C310	Statistical Physics	C	4
PHY C311	Nuclear and Elementary Particle Physics	C	4
PHY C312	Condensed Matter Physics	C	4
PHY E305	Introduction to Nanoscience	E	3
PHY E306	General Relativity and Cosmology	E	3
UOM S003	Soft skill	S	2
	IV SEMESTER		
PHY C313	Elements of Spectroscopy	C	4
PHY C314	Project work & Viva voce	C	6
PHY E307	Theory of Nano-solids	C	3
PHY E308	Astrophysics and Advanced Nuclear Theory	E	3
PHY E309	Advanced Topics in Mathematical Physics	E	3
PHY E310	Quantum Field Theory	E	3
PHY E311	Band Gap Engineering in Semiconductors	E	3
PHY E312	Introduction to Bose-Einstein Condensation (BEC), Superfluidity and Superconductivity	E	3
PHY E313	Crystal Growth and Thin Film Physics	E	3
UOM S004	Soft Skill	S	2

MATHEMATICAL PHYSICS

TP PHY C 301

No. of credits: 4

UNIT 1: **VECTOR SPACES:** Definition, Examples, Scalar Product, Cauchy-Schwartz inequality; Linear Independence, Orthogonality; Gram-Schmidt procedure; Operators, Representations of Vectors and Operators.

UNIT 2: **MATRICES:** Types of Matrices and their properties, Rank of a Matrix, Eigenvalue Equations and their solutions, Theorems on Matrices; Diagonalisation and Diagonalisation of different matrices; Cayley-Hamilton's theorem; Problems.

UNIT 3: **COMPLEX ANALYSIS:** Review of Complex Numbers (deMoivre's theorem, n^{th} root of unity,..); Functions of a Complex Variable; Differentiability & Analyticity; Harmonic Functions; Complex Integration; Contour Integration, Cauchy's Integral Theorem & Formula; Taylor's Series & Laurent's Expansion; Calculus of Residues (Initial part).

UNIT 4: The Dirac Delta Function – Definition, properties and problems; Partial Differential Equations – Method of Separation of Variables in Rectangular, Spherical and Cylindrical Co-ordinate systems**;** The Green's Function Method for Inhomogenoous Differential Equations; Sturm-Liouville Theory.
.

UNIT 5: **LAPLACE TRANSFORMS & FOURIER TRANSFORMS:** Definitions; Transforms of Different Functions; Properties; Convolution theorem; Applications to Differential Equations.
Co-ordinate Systems: Rectangular, Spherical and Cylindrical Co-ordinate

BOOKS FOR STUDY

1. George Arfken and Hans J Weber, ***Mathematical Methods for Physicists*** – A Comprehensive Guide (7^{th} edition), Academic press.
2. P. K. Chattopadhyay, ***Mathematical Physics***, Wiley Eastern, New Delhi, 1992.
3. Tulsidass and S K Sharma, ***Mathematical Methods in Classical and Quantum Physics.***
4. S. S. Rajput, ***Mathematical Physics***, Pragati Pragasan, Meerut, 11th Edition, 1996.
5. A W Joshi, ***Matrices and Tensors in Physics***
6. Charlie Harper, ***Introduction to Mathematical Physics,*** California State University, Hayward**.**
7. B. D. Gupta, ***Mathematical Physics***, Vikas Publishing House Pvt. Ltd, New Delhi, 2004.
8. A.K.Ghatak, I.G.Goyal and A.J.Chua, ***Mathematical Physics***, Mc-Millan.

BOOKS FOR REFERENCE

1. E. Kreyszig, ***Advanced Engineering Mathematics***, Wiley Eastern, New Delhi, 1983.
2. D. G. Zill and M. R. ***Cullen, Advanced Engineering Mathematics***, 3rd Ed. Narosa, New Delhi, 2006.

3. L. A. Pipes and L.R. Harvill, ***Applied Mathematics for Engineers and Physicists***, McGraw Hill, London, 1970.
4. Murray. R. Spiegel, ***Vector Analysis***, Schaum's outline series, McGraw Hill, New York,1974.
5. M.D. Greenbey, ***Advanced Engineering Mathematics***, 2nd Edition, Prentice-Hall.
6. C.R. Wylie and L.C. Barrett, ***Advanced Engineering Mathematics***, McGraw Hill, New York, 5th Edition.

ELECTRONICS

TPPHY C302

No. of credits: 4

UNIT 1: **SEMICONDUCTOR DEVICES:** Semiconductors – Elemental, binary and ternary semiconductor oxides – Layered semiconductors – Energy bands – transition between bands – carrier concentration. FET, MOSFET, UJT, SCR, TRIAC – structure, working and characteristics – FET amplifier – UJT relaxation oscillator – SCR/ TRIAC for power control.

UNIT 2: **MICROWAVE DEVICES:** Tunnel diode – Transfer electron, Gunn Diode (transfer electron device) – Avalanche transit time devices and impatt diodes. Photonic Devices: Photoconductive sensors – Junction type photoconductors: (a) PN photodiodes (b) PIN photodiodes (c) Avalanche photodiode (d) NPN photoduo diode (e) phototransistors and applications. Recent Advances in Technology: Introduction to nano – electronics and spintronics.

UNIT 3: **DIGITAL ELECTRONICS:** Counters and registers, Synchronous counters, Design of counters of different modulus – Shift registers and their applications. Semiconductors memories: ROM, EPROM, EEPROM – Static and Dynamic RAM.

UNIT 4: **APPLICATIONS OF OP AMPS:** Binary weighted ladders – Digital to analog converter - Accuracy and resolution of DAC – A to D converters – Counter method conversion, Continuous Conversion, Dual slope conversion methods – Successive approximation – Accuracy and resolution of ADC. Differential DC Amplifier – Instrumentation amplifier – Phase locked loop – Peak detector, Zero crossing detector – Stable AC coupled amplifier – Analog integration and differentiation – Solution to simultaneous and differential equations using Op Amps – Active filters – Comparator – Sample and hold circuit – Logarithmic amplifiers – Waveform generators – Regenerative comparator – Rectifier circuits – phase shift circuit – 555 Timer – Applications.

BOOKS FOR STUDY AND REFERENCE

1. Peter Y. Yu, Manuel Cardona, ***Fundamentals of Semiconductors Physics and Materials Properties***, Springer, (14^{th} Edn.)
2. S.M. Sze, ***Semiconductor Devices – Physics and Technology***, John Wiley, New York (2^{nd} Edn.)
3. Allen Mottershead, ***Electronic Devices and Circuits - An Introduction.***
4. Malvino and Leach, ***Digital Principles and Applications***, Tata McGraw Hill, (4^{th} Edn.)
5. Herbert Taut and Donald Schilling, ***Digital Integrated Electronics***, McGraw Hill International Edn.
6. Janet Millman and Christos C. Halkias, ***Integrated Electronics - Analog and Digital Circuits and Systems***, McGraw Hill.
7. R.A Gayakwad, ***Op Amps and Linear Integrated Circuits***, Prentice Hall of India Pvt. Ltd (4^{th} edn.)
8. Richard A. Honeycutt, ***Op Amps and linear integrated circuits***, Delmar publishers

CLASSICAL MECHANICS

TPPHY C303

No. of credits: 4

UNIT 1: **REVIEW OF NEWTON'S LAWS,** Mechanics of a particle, Mechanics of a system of particles, Frames of references, rotating frames, Centrifugal and Coriolis force, Constraints, D'Alembert's principle and Lagrange's equations, Velocity dependent potentials and the dissipation function, Simple applications of the Lagrangian formulation. Hamilton's principle, Calculus of variations, Derivation of Lagrange's equations from Hamilton's principle, Lagrange Multiplier, Extension of Hamilton's principle to non-holonomic systems, Advantages of a variational principle formulation, Hamilton's principle, Calculus of variation and its application to geodiscs and surface of revolutions, Derivation of Lagrange's equation from Hamilton's principle, Lagrange's equation for non-holonomic systems (method of undetermined multipliers), Principle of least action, Conservation theorems and symmetry properties, Energy function and the conservation of energy.

UNIT 2: **THE TWO-BODY CENTRAL FORCE PROBLEM:** Reduction to the equivalent one body problem, The equations of motion and first integrals, The equivalent one-dimensional problem and classification of orbits, The Virial theorem, The differential equation for the orbit and integrable power-law potentials, The Kepler problem: Inverse square law of force, The motion in time in the Kepler problem, Scattering in a central force field, Scattering in a central force field, Rutherford scattering, Transformation of co-ordinates from LAB to CM.

UNIT 3: Legendre transformations and the Hamilton equations of motion, cyclic coordinates and conservation theorems, Canonical Transformations: Generating functions, properties, Examples of canonical transformations, Poisson brackets and other canonical invariants, infinitesimal canonical transformations and conservation theorems in the Poisson bracket formulation, The angular momentum Poisson bracket relations.

UNIT 4: Hamilton-Jacobi equation for Hamilton's principle-function, Application to Harmonic oscillator problem, Hamilton equation for Hamilton's characteristic function, separation of variables and applications to particle motion under central force, Action angle variables.

UNIT 5: **SMALL OSCILLATIONS:** Formulation of the problem, The eigenvalue equation and the principal axis transformation, Frequencies of free vibration and normal coordinates, Motion of a rigid body, Euler angles, the Euler equations of motion of rigid bodies, body and space reference system, angular momentum and inertia tensor, Principle axes- Principle moments of inertia, spinning tops, infinitesimal rotations.

BOOKS FOR STUDY AND REFERENCE

1. H. Goldstein, ***Classical Mechanics,***Poole and Safco, 3rd Edition, Narosa Publication (2001)
2. L.D. Landau and E.M., ***Mechanics***, Lifshitz Pergamon Press (1960).
3. Marion and Thornton, ***Classical Dynamics of Particles and Systems,*** 2nd ed., 1970.
4. Donald T. Greenwood, ***Classical Mechanics***, Prentice – Hall of India Pvt. Ltd.
5. K.C. Gupta, ***Classical Mechanics of Particles and Rigid Bodies***, Wiley Eastern.
6. N.C. Rana and P.J. Joag, ***Classical Mechanics***, Tata McGraw Hill.
7. J.Michael Finn, ***Classical Mechanics***, Infinity Science Press LLC.
8. Satyendra Nath Maitti, Debi Prasad Raychaudhuri, ***Classical Mechanics and general properties of***

Matter, New Age International Publishers.
9. J.C.Upadhaya, ***Classical Mechanics***, Himalaya Publishing House Pvt. Ltd.
10. G. Aruldhas, ***Classical Mechanics***, Eastern Economy Edition.

SPECIAL FUNCTIONS AND THEIR APPLICATIONS

TPPHY E302

No. of credits: 3

UNIT 1: **GAMMA AND BETA FUNCTIONS**: Integral representations – Intimate relationships – Applications in Hermite, Legendre, and Laguerre polynomials – Bose Integrals – Fermi Integrals – Riemann zeta functions – Dirichlet eta functions – Simple applications of dimensional analysis in Gamma and Beta functions and Power Laws in Physics (Stefan-Boltzmann Law, Beauty of σ, the Stefan-Boltzmann Constant; Debye T^3 Law; Bloch $T^{3/2}$ Law; …).

UNIT 2: **GENERATING - FUNCTION METHOD**: Hermite, Legendre, and Laguerre polynomials – Development of their properties.

OPERATOR FORMALISM FOR HERMITE POLYNOMIALS: Arfken's Formula, Bell's formula, and Rodrigues' representation.

UNIT 3: **ZEROS:** Properties of the Zeros of orthogonal polynomials – Graphs of Real Orthogonal polynomials – Interlacing of the Zeros of the Hermite polynomials– Harmonic Oscillator wave function cutting the Zero-Line.

UNIT 4: **POWER SERIES SOLUTIONS AND SPECIAL FUNCTIONS:** Taylor series method – Legendre differential equation, special case of polynomial solutions **-**Legendre polynomials.

FROBENIUS METHOD – Regular singular point **-** Root of indicial equation unequal but not differing by an integer - Root of indicial equation unequal but differing by an integer - Bessel's equations of order n (n is not an integer), of order n (where n is an integer positive), connection between Bessel's function of the first kind and gamma function.

UNIT 5: **LANGEVIN FUNCTION, BRILLOUIN FUNCTIONS, AND APPLICATIONS OF SPECIAL FUNCTIONS**: Langevin function – Brillouin functions – Economized Power Series using Chebyshev polynomials – Illustrative examples from Physics (Statistical Mechanics, Thermodynamics, Electromagnetic Theory, Condensed Matter Physics, Quantum Mechanics) – Simple applications of dimensional analysis in Langevin function, Brillouin functions, and illustrative examples.

BOOKS FOR STUDY

1. E D Rainville, ***Special Functions***.
2. W W Bell, ***Special Functions for Scientists and Engineers.***
3. G B Arfken and H J Weber, ***Mathematical Methods for Physicists***, 5th Edition.
4. E. Kreyszig, ***Advanced Engineering Mathematics***, 10th Edition.

BOOKS FOR REFERENCE

1. M Abramowitz and I A Stegun (Editors), ***Handbook of Mathematical Functions.***
2. E D Rainville and P E Bedient, ***Elementary Differential Equations,*** 5th Edition.
3. L C Andrews, ***Special Functions for Engineers and Applied Mathematicians***, 2nd Edition.
4. H K Crowder & S M McCuskey, ***Topics in Higher Analysis.***

NUMERICAL METHODS AND COMPUTER PROGRAMMING

TPPHY C305

No. of credits: 4

UNIT 1: **SOLUTION OF NUMERICAL, ALGEBRAIC AND TRANSCENDENTAL EQUATIONS:** Bisection method – Repeated application of location theorem – Method of interpolation or of False position (Regula Falsi method) – Repeated plotting on a large scale – Newton Raphson method – Geometic significance of Newton Raphson method – Method of successive approximation or iteration.

UNIT 2: **INTERPOLATION:** Differences – Horizontal and Diagonal differences – Differences of a polynomial – Interpolation with equal intervals of arguments: Newton's formula for forward, backward interpolation. Interpolation with unequal intervals of arguments: Divided differences – Newton's central difference method

UNIT 3: **NUMERICAL DIFFERENTIATION:** Stirlings formula & differentiation – with other appropriate interpolation formulae.

NUMERICAL SOLUTION OF FIRST ORDER DIFFERENTIAL EQUATIONS: Euler- Runge – Kutta methods.

SOLVING SIMULTANEOUS LINEAR EQUATIONS: Gauss Elimination method – Jordan's modification.

NUMERICAL INTEGRATION: Trapezoidal rule – Romberg's method (and Richardson's deferred approach) - Simpson's rule – extended Simpson's one third rule – Applications in Physics.

UNIT 4: **COMPUTER PROGRAMMING IN FORTRAN 90:** Evolution of Fortran 90 - Logging in to Linux terminals in LAN. Using text editor in Linux. Fortran 90 compiler in Linux: compilation, linking and running of programs. Writing simple Fortran 90 programs. Numeric constants and variables - Arithmetic expressions - Input and Output statements - Conditional statements - Loops in Fortran 90 - Logical expressions - Functions and subroutines - Arrays - Additional features in Fortran 90: Recursive functions. User defined operators.

List of Experiments in the Laboratory:

1. Determination of root of equation by bisection method
2. Determination of root of equation by Newton Raphson method
3. Determination of all real roots of a quartic/cubic equation by Newton Raphson Method with subroutine subprograms
4. Lagrange interpolation
5. Newton Forward interpolation
6. Newton Backward interpolation
7. Newton Forward interpolation with subroutine subprograms
8. Newton Backward interpolation with subroutine subprograms
9. Maxima and Minima of a tabulated function with subroutine subprograms
10. Maxima and Minima of a gamma function with subroutine subprograms
11. Integration by Trapezoidal rule

12. Integration by Simpson's rule
13. Integration by Gauss-Legendre Quadrature
14. Integration by Gauss-Chebyshev Quadrature
15. Integration by Gauss-Hermite Quadrature
16. Integration by Gauss-Laguerre Quadrature
17. Determination of zeroes of Legendre Polynomials
18. Determination of zeroes of Laguerre Polynomials
19. Determination of zeroes of Hermite Polynomials
20. Determination of zeroes of Chebyshev Polynomials

BOOKS FOR STUDY AND REFERENCE

1. J. B. Scarborough, ***Solutions of Numerical equations.***
2. Daniel D. Mccracken and William S. Dorn, ***Numerical methods and FORTRAN programming (with application in engineering and science)***
3. John H. Mathews, ***Numerical methods for mathematics, science and engineering***.
4. M. K. Venkataraman , ***Numerical methods in science and engineering***.
5. M. K. Jain, S. R. K. Iyengar, R. K. Jain, ***Numerical methods for scientific and engineering computation.***
11. Sameual D. Conte and Carl de boor, ***Elementary Numerical Analysis – An algorithmic approach.***
12. V. Rajaraman, ***Computer Programming in FORTRAN 90 and 95***, PHI Learning Private Limited. 2011
13. S. Chapman, ***FORTRAN 90/95 for Scientists and Engineers***
14. M. Metcalf and J. Reid, ***Fortran 90/95 Explained***

ELECTROMAGNETIC THEORY

TPPHY C306

No. of credits: 4

UNIT 1: Vector Analysis Vector Algebra: Differential Calculus - Integral Calculus - Curvilinear Coordinates - The Dirac Delta Function - The Theory of Vector Fields -

UNIT 2: **ELECTROSTATICS:** The Electrostatic Field - Divergence and Curl of Electrostatic Fields - Electric Potential - Work and Energy in Electrostatics - Conductors - Special Techniques - Laplace's Equation and Uniqueness Theorems - The Method of Images - Separation of Variables - Multipole Expansion - Electrostatic Fields in Matter -: Polarization - The Field of a Polarized Object - The Electric Displacement - Linear Dielectrics -

UNIT 3: **MAGNETOSTATICS:** The Lorentz Force Law - The Biot-Savart Law - The Divergence and Curl of B - Magnetic Vector Potential - Magnetic Fields in Matter - Magnetization - The Field of a Magnetized Object - The Auxiliary Field H - Linear and Nonlinear Media.

UNIT 4: **ELECTROMAGNETIC WAVES:** Electromotive Force - Electromagnetic Induction - Maxwell's Equations, Conservation Laws: Charge and Energy - Momentum, Waves in One Dimension - Electromagnetic Waves in Vacuum - Electromagnetic Waves in Matter - Absorption and Dispersion - Guided Waves.

UNIT 5: **POTENTIALS AND FIELDS:** The Potential Formulation - Continuous Distributions, Radiation: Dipole Radiation - Point Charges.

Electrodynamics and Relativity: The Special Theory of Relativity - Relativistic Mechanics - Relativistic Electrodynamics.

BOOKS FOR STUDY AND REFERENCE

1. David J. Griffiths, ***Introduction to Electrodynamics.***
2. J.D. Jackson: ***Classical Electrodynamics***, 3rd edition, John Wiley.
3. John R. Reitz, Frederick J. Milford and Robert W. Christy: ***Foundations of Electromagnetic Theory***, 4th ed., 1992.
4. Joseph A. Edminister, ***Schaum's Outline of Electromagnetics***.
5. E.C. Jordan and K. G. Balmin, ***Electromagnetic waves and radiating system***, second edition, Prentice-Hall, India

QUANTUM MECHANICS - I

TPPHY C307

No. of credits: 4

UNIT 1: **INTRODUCTION**: Brief review of Old Quantum Theory; The Stern-Gerlach experiment and discussion; Need for a new Quantum theory.

UNIT 2: **SCHROEDINGER EQUATION** & **BASIC FORMALISM**: Interpretation of and conditions on the wave function; Ehrenfest's theorem; Stationary States; Postulates of Quantum Mechanics; Brief Review of Vector Spaces; Hermitian Operators for Dynamical Variables; Eigenvalues and Eigenfunctions; Generalized Uncertainty principle; Identical particles; Symmetry and antisymmetry of wavefunctions

UNIT 3: **EXACTLY SOLVABLE PROBLEMS IN ONE DIMENSION**: Stationary states: time independent Schrodinger equation - Free particle and Box normalization; Particle in a box - Particle in a square well potential – Bound states –eigenvalues, eigenfunctions - nonlocalized states –potential barrier – quantum mechanical tunneling - multiple potential well - Periodic potentials & energy bands - Simple harmonic oscillator (differential equation method - Ladder operator methods); Problems.

UNIT 4: **THREE DIMENSIONAL PROBLEMS**: Particle in a Central Potential; Angular momentum and Spherical Harmonics; Parity; Particle in a spherical well; Hydrogen atom; Charged particle in a uniform magnetic field.

UNIT 5: **ANGULAR MOMENTUM**: Commutation relations; Eigenvalue spectrum; Spin angular momentum states; Pauli matrices; Addition of angular momenta; C.G. Coefficients.

BOOKS FOR STUDY AND REFERENCE

1. P. M. Mathews and K Venkatesan, ***A text book of Quantum Mechanics***, second edition, Tata McGraw-Hill.
2. Nouredine zettili, ***Quantum Mechanics Concepts and Applications,*** John Wiley & Sons.
3. Claude Cohen-Tannoudji, Bernard Diu, Franck Laloe, ***Quantum Mechanics*** –Vol. I — John Wiley Interscience Publications.
4. V. K. Thankappan, ***Quantum Mechanics,*** 2nd Edition, New Age International (P) Ltd.
5. E. Merzbacher, ***Quantum Mechanics***, third edition, McGraw-Hill.
6. Leonard I. Schiff, ***Quantum Mechanics***, McGraw-Hill International Publication.
7. David J. Griffiths, ***Introduction to Quantum Mechanics***, Prentice-Hall, 1995.
8. B. H. Bransden and C. J. Joachain, ***Quantum Mechanics***, Second Edition, Prentice-Hall, 2000.
9. A. K. Ghatak and Lokanathan, ***Quantum Mechanics – Theory and Applications***, 5th Edition, Macmillan India Ltd Publication.
10. R. Shankar, ***Principle of Quantum Mechanics,*** 2nd Edition, Plenum US Publication.

ELEMENTARY QUANTUM MECHANICS
(for other department students only)

TPPHY E303

No. of credits: 3

UNIT 1: **INTRODUCTION**: Old Quantum Theory; Bohr – Sommerfeld conditions and applications; Review of experiments – the Stern – Gerlach experiment and discussion. Need for a new Quantum theory.

UNIT 2: **THE SCHROEDINGER EQUATION**: Postulates of Quantum Mechanics; Concepts of Quantum States, Operators and their significance; The Schrodinger equation, its significance and its applications to the free particle, the simple harmonic oscillator, particle in a central potential, the hydrogen atom.

UNIT 3: **ANGULAR MOMENTUM & APPROXIMATION METHODS**: Ideas of angular momentum and its addition; Time – independent Perturbation theory; Variational method; Applications of these methods.

BOOKS FOR STUDY

1. Aruldhas, ***Quantum Mechanics***.
2. Leonard I. Schiff, ***Quantum Mechanics***, McGraw-Hill International Publication.
3. David J. Griffiths, ***Introduction to Quantum Mechanics***, Prentice-Hall, 1995.

MATHEMATICAL TECHNIQUES

TPPHY E304

No. of credits: 3

UNIT 1: **CURVILINEAR COORDINATES**: Orthogonal coordinates - Jacobian for polar coordinates – Differential vector operators: gradient, divergence, and curl – circular cylindrical coordinates – spherical polar coordinates.

UNIT 2: **COMPLEX ANALYSIS**: Power Series expansions: Taylor and Laurent expansions – poles, residues and singularities - Residue Theorem and its applications: Evaluation of definite integrals and poles on the real axis.

UNIT 3: **STURM-LIOUVILLE THEORY OF SECOND ORDER LINEAR DIFFERENTIAL EQUATIONS**: Orthogonality of eigenfunctions – Reality of eigenvalues – Chebyshev, Hermite, Laguerre and Legendre differential equations as examples – Zeros, Wronskian and singular points.

UNIT 4: **TENSORS**: Cartesian vectors and tensors: illustration with moment of inertia, conductivity, dielectric tensors – contravariant and covariant vectors and tensors, mixed tensors – tensor algebra: addition, subtraction, direct product of tensors - symmetric and anti symmetric tensors.

UNIT 5: **GREEN'S FUNCTION**: Mathematical definition of Green's function, Green's functions in the solutions of differential equations: construction of Green's functions – solution to the Poisson's equation in electrostatics (classical problem) - quantum mechanical solution to the Schroedinger's time dependant equation.

BOOKS FOR STUDY

1. Eugene Butkov, ***Mathematical Physics.***
2. Erwin Kreyszig, ***Advanced Engineering Mathematics***, 10th edition.
3. G. Arfken and H. Weber, ***Mathematical Methods for Physicists,*** 6th edition.
4. K. F. Riley, M. P. Hobson, S. J. Bence, ***Mathematical methods for physics and engineering***, 3rd edition.
5. L. A. Pipes and L. R. Harvill, ***Applied Mathematics for Engineers and Physicists,*** 3rd edition.

BOOKS FOR REFERENCE

1. E. A. Lord, ***Tensors, Relativity and Cosmology.***
2. P. M. Mathews, K. Venkatesan, ***A textbook of quantum mechanics.***
3. G. Rickayzen, ***Green's function and condensed matter.***
4. P.K. Chattopadhyay, ***Mathematical Physics.***
5. A. W. Joshi, ***Matrices and Tensors in Physics.***

QUANTUM MECHANICS - II

TPPHY C309

No. of credits: 4

UNIT 1: **GENERAL FORMALISM**: Hilbert Space, Dirac notation; representation theory; co-ordinate and momentum representations, time evolution; Schrodinger, Heisenberg and Interaction pictures; Symmetries and Conservation laws; unitary transformations associated with translational and rotations, parity and time reversal.

UNIT 2: **APPROXIMATION METHODS:** Time-independent, non-degenerate and degenerate Perturbation Theory and its applications - Effect of electric field (stark effect) on ground state of Hydrogen atom - two electron atom. Variational method and applications - ground state of Helium atom – WKB approximation; connection formulae; WKB quantization rule and applications.

UNIT 3: **TIME EVOLUTION PROBLEMS:** Time dependent Perturbation theory - first order transitions – constant perturbation- transition probability: Fermi Golden Rule –Periodic perturbation –harmonic perturbation –adiabatic and sudden approximation - Semi-classical theory of radiation: Application of the time dependent perturbation theory to semi-classical theory of radiation – dipole transition - selection rules – forbidden transitions.

UNIT 4: **SCATTERING THEORY:** General Description; definitions; Scattering differential cross section and scattering amplitude; Expression for Scattering amplitude using Green function's method; Born Series and first Born approximation and scattering amplitude; Application of Born Approximations; Phase shift analysis and scattering amplitude and cross section.Applications to various systems; s-wave scattering, effective range theory; Zero energy and low energy scattering discussions; Two-body scattering in center-of-mass frames and laboratory frames; scattering of identical particles.

UNIT 5: **RELATIVISTIC QUANTUM MECHANICS:** Klein Gordon Equation and associated problems; The Dirac equation; properties of alpha, beta matrices. Solution to free Dirac equation. Spin of the Dirac particle. Dirac equation in a Central (Coulomb) potential; Lorentz covariance of the Dirac equation; Gamma matrices and properties. Lorentz covariance of continuity equation; Bilinear covariants and Lorentz transformation properties.

BOOKS FOR STUDY AND REFERENCE

1. PM Mathews and K Venkitesan, ***A text book of Quantum Mechanics***, second edition, Tata McGraw Hill
2. E. Merzbacher, ***Quantum Mechanics***, third edition, McGraw-Hill.
3. Nouredine zettili, ***Quantum Mechanics Concepts and Applications***, John Wiley & Sons
4. Leonard I. Schiff, ***Quantum Mechanics***, McGraw-Hill International Publication.
5. David J. Griffiths, ***Introduction to Quantum Mechanics***,(Prentice Hall, 1995)

6. B. H. Bransden and C. J. Joachain, ***Quantum Mechanics***, Second Edition" by (Prentice-Hall, 2000).
7. A.K.Ghatak and Lokanathan, ***Quantum Mechanics – Theory and Applications***, 5th Edition, Macmillan India Ltd Publication,
8. R.Shankar, ***Principle of Quantum Mechanics,*** 2nd Edition, Plenum US Publication.
9. V. K. Thankappan, ***Quantum Mechanics***, 2nd Edition, New Age International (P) Ltd.
10. Claude Cohen-Tannoudji, Bernard Diu, Franck Laloe, ***Quantum Mechanics*** –Vol. II — John Wiley Interscience Publications.

STATISTICAL PHYSICS

TPPHY C310

No. of credits: 4

UNIT 1: **THERMODYNAMICS**: Brief Introduction on - Equation of state for various thermodynamic systems; Laws of Thermodynamics; Consequences of equations of state and Thermodynamics laws; thermodynamics potentials; Maxwell's relations - Thermodynamic equilibrium conditions - Phase equilibrium; Gibbs' phase rule, phase transitions; Van der Waal's gas – Maxwell construction- Ehrenfest's classification.

UNIT 2: **CLASSICAL STATISTICAL MECHANICS**: Postulates; Liouville's theorem, microcanonical, canonical & grand canonical ensembles; Virial theorem & Equipartition of Energy theorem in these ensembles; equivalence of these ensembles; expressions for entropy in terms of probability in these ensembles; applications of these ensembles to classical ideal gas, N harmonic oscillators; Langevin's theory of paramagnetism.

UNIT 3: **QUANTUM STATISTICAL MECHANICS:** Postulates of Quantum Statistical Mechanics; Density operator and matrix; applications to electron in a magnetic field, free particle, harmonic oscillator, and to multiparticle systems; Ideal Bose and Fermi gases in micro-canonical and Grand canonical ensembles; Bose-Einstein and Fermi-Dirac distributions; equations of state.

UNIT 4: **APPLICATIONS OF FERMI STATISTICS:** Degenerate Fermi gas, low temperature expansion of electronic specific heat; Pauli's theory of paramagnetism; Landau's theory of diamagnetism.
Applications of Bose Statistics : Black body radiation; Debye theory for specific heat; Bose-Einstein condensation

UNIT 5: **SPIN SYSTEMS:** Ising model: 1D Ising model; mean field theory; Bragg Williams approximation; 2D Ising Model (if possible)

BOOKS FOR STUDY

1. Sears & Salinger, ***Thermodynamics, Kinetic Theory & Stat. Thermodynamics***
2. R. K. Pathria, ***Statistical Mechanics***
3. Kerson Huang, ***Introduction to Statistical Physics/ Statistical Mechanics***
4. F. Reif, ***Fundamentals of Statistical and Thermal Physics***
5. Greiner, Neise and Stoecker, ***Thermodynamics and Statistical Mechanics***

BOOKS FOR REFERENCE

1. L.D. Landau and E.M. Lifshitz, ***Statistical Physics, Part 1***
2. L.E. Reichl, ***A Modern Course on Statistical Physics***
3. P.M. Morse, ***Thermal Physics***
4. D.J. Amit and Y. Verbin, ***Statistical Physics, An Introductory Course***
5. Shang-Keng Ma, ***Statistical Mechanics***

NUCLEAR & ELEMENTARY PARTICLE PHYSICS

TPPHY C311

No. of credits: 4

UNIT 1: **NUCLEAR FORCES**: Nucleon - nucleon interactions; Exchange forces and tensor forces; Meson theory of nuclear forces; Nucleon-nucleon scattering; Singlet and triplet parameters; Charge independence; Isospin; Ground state of the deuteron; Magnetic moment; Quadrupole moment; S and D state admixtures.

UNIT 2: **NUCLEAR MODELS:** Shell models; Spin-orbit coupling; Spins of nuclei; Magnetic moments; Schmidt lines; Liquid drop model; Bohr-Wheeler theory of fission; Collective model of Bohr and Mottelson

UNIT 3: **BETA DECAYS**: Beta decay; Energy release in beta decay; Fermi theory of beta decay; Shape of the beta spectrum; Total decay rate; Angular momentum and parity selection rules; Comparitive half-lives and forbidden decays; Non-conservation of parity

UNIT 4: **GAMMA DECAYS:** Gamma decay and energetics; Multipole radiation; Angular momentum and parity selection rules; Internal conversion; Nuclear isomerism

UNIT 5: **ELEMENTARY PARTICLE PHYSICS**: Interactions between elementary particles; Hadrons and Leptons; Symmetry and Conservation laws; CPT theorem; Classification of hadrons; Lie algebra, SU(2)-SU(3) multiplets; Quark model; Gellmann - Okubo mass formula for octed and decuplet hadrons; Phenomenology of weak interaction of hadrons and leptons; Universal Fermi interaction; Elementary concepts of V - A theory of weak interactions.

BOOKS FOR STUDY AND REFERENCE

1. J. M. Blatt, V. F. Weisskopf, ***Theoretical Nuclear Physics***, Springer-Verlag New York Inc. (1979).
2. *A Bohr & B R Mottelson* , ***Nuclear Structure,*** World Scientific, (1969).
3. R.R. Roy and B.P. Nigam, ***Nuclear Physics,*** New Age International, New Delhi (2005)
4. *David Griffiths*, ***Introduction to Elementary Particles,*** by John wiley & sons, Inc. 1897
5. V.Devanathan, ***Nuclear Physics,*** Norosa Publishing House, New Delhi, (2011).

CONDENSED MATTER PHYSICS

TPPHY C 312

No. of credits: 4

UNIT 1: **CRYSTAL PHYSICS:** ***Crystal Structure*:** Lattice representation - Simple symmetry operations - Bravais Lattices, Unit cell, Wigner -Seitz cell - Miller planes and spacing - Characteristics of cubic cells - Structural features of NaCl, CsCl, Diamond, ZnS – Close packing.

Diffraction: Bragg's law - Reciprocal representation - Diffraction conditions and Laue equations - Brillouin zones for cubic lattices - Rotation, Laue and Powder methods of X-ray diffraction (an overview only) - Concepts of Scattering , Structure and Temperature factors.

Crystal Binding: Interactions in inert gas crystals and cohesive energy - Interactions in ionic crystals and Madelung energy - Overview of Covalent, metal and hydrogen bonded interactions.

UNIT 2: **LATTICE DYNAMICS:** Theory of elastic vibrations in mono and diatomic lattices - Phonons – Dispersion relations - Phonon momentum.

***Heat Capacity*:** Vibrational modes - Einstein model - Density of modes in one and three dimensions - Debye Model of heat capacity.

Anharmonic effects: Explanation for Thermal expansion, Conductivity and resistivity – Umklapp process.

UNIT 3: **Unit 3: THEORY OF ELECTRONS IN SOLIDS:**

***Free electron theory*:** Energy levels and Fermi Dirac distribution (review) - Free electron gas in 3D - Density of States –Fermi sphere – Fermi surface - Heat capacity of the electron gas - Electrical and thermal Conductivity in metals - Lorentz number – Effect of magnetic field on Fermi sphere - *Hall effect.*
Energy bands: Nearly free electron model in periodic lattices – origin of energy gaps - Wave equation in periodic potential - The Bloch theorem –
One Dimensional Approach: The Kronig-Penny Model - Reduced, Periodic and Extended Zone Schemes- number of electrons per band- effective mass of an electron distinction between metals, insulators and intrinsic semiconductors -Concept of the hole -Limitations of K-P model
The Many-Electron Problem: The One – Electron Approximation - The Hartree Method.The Hartree Method and the Variational Principle - The Hartree – Foch Method.
Density Functional Theory - An overview Kohn-Hohenberg Theorems - Kohn-Sham equation. Band Structure Methods – An Outline**:** **S**olid potential – a one dimensional view – Choice of potential and wave function for real solid - Energy - Band Methods (Introduction only).
Fermi Surfaces: Reduced zone and periodic zone schemes of construction - Construction of Fermi surfaces - Experimental studies of Fermi surfaces – *de Hass van Alphen* effect.
Quantum Confinement in Nano Soilds: Quantum mechanics in reduced dimension- Band, quasi band and discrete nature of energy- 2D,1D and 0D Density of States (DOS)- Idealized

quantum well-Idealized quantum wire-Idealized cubic quantum dot. Excitons in Nano Semiconductors - *Quantum Size Effects in Finite Semiconductor*-Quantum confinement and Morphology.

UNIT 4: **MAGNETISM:** Diamagnetism - Quantum theory of paramagnetism - Rare earth ion – Hund's rule - Quenching of orbital angular momentum - Adiabatic demagnetization – Quantum theory of ferromagnetism - Curie point - Exchange integral - Heisenberg's interpretation of weiss field – Ferromagnetic domains - Bloch Wall - Spin Waves – Quantization - Magnons - Thermal excitation of magnons - Curie temperature and susceptibility of ferrimagnets - Theory of antiferromagnetism – Neel temperature.

UNIT 5: **SUPERCONDUCTIVITY:** Occurrence - Effect of magnetic fields - Meissner effect – Entropy and heat capacity – Energy gap - Microwave and infrared properties - Type I and II Superconductors.

Theoretical Explanation: Thermodynamics of superconducting transition – London equation – Coherence length – BCS Theory – Single particle tunneling – DC & AC Josephson effect – High temperature Superconductors – SQUIDS.

BOOKS FOR STUDY

1. Charles Kittel, ***Introduction to Solid State Physics,*** **7th Edition**, Wiley India Pvt. Ltd. , New Delhi, 2004.
2. Rita John, ***Solid State Physics,*** Tata Mc Graw Hill Publications, 2014.
3. M. Ali Omar, ***Elementary Solid State Physics – Principles and Applications,*** Pearson, 1999.

BOOKS FOR REFERENCE

1. J. Blakemore, ***Solid State Physics, 2nd Edition,*** W. B. Saunders Co, Philadelphia, 1974.
2. C. M. Kachhava, ***Solid State Physics,*** Tata Mcgraw Hill, New Delhi, 1990.
3. S. L. Altmann, ***Band Theory of Metals,*** Peragamon, Oxford.
4. N. W. Aschroft and N. D., Mermin, ***Solid State Physics,*** Rhinehart and Winton, New York.
5. M. Tinkham, ***Introduction to Superconductivity,*** Tata Mcgraw Hill, New Delhi, 1996.
6. A. J. Dekker, ***Electrical Engineering Materials***, Prentice Hall of India.
7. M. A. Wahab, ***Solid State Physics – Structure and Properties of Materials.*** Narosa, New Delhi, 1999.
8. S.O. Pillai, ***Problems and Solutions in Solid State Physics,*** New Age international Publishers, New Delhi, 1994.
9. Alexander O. E. Animalu, ***Intermediate Quantum Theory of Crystalline solids,*** Prentice Hall of India, New Delhi, 1978.
10. Eleftherios N. Economou, ***The Physics of Solids – Essentials and Beyond,*** Springer, 2010.
11. Rita John *(Edited)* ***Condensed Matter Theory,*** *Edited by*, UGC Academic Staff College, University of Madras, 2010.
12. L. Solymar and D. Walsh, Lectures ***on the Electrical properties of materials, Clarendon*** Press , Oxford, 1970.

INTRODUCTION TO NANO SCIENCE

TPPHY E305

No. of credits: 3

UNIT 1: **PHYSICS OF BULK SOLID:** Atomic structure – Energy levels in atoms – Transition between energy levels – Bonding in solids – formation of bands - Crystal physics – Brillouin zones - types of crystals – Symmetry - Crystal planes and directions – Miller indices.

Free electrons in solid – Density of states – Fermi dirac distribution - Fermi surfaces – Effective masses.

Insulators , Semiconductors and Conductors – Direct and Indirect Band Gaps – Localized particles – Donars, Acceptors and Deep traps – Mobility- Excitons.

UNIT 2: **PHYSICS OF NANO SOLIDS:** Definition of nanoscience and background – Importance of nano science size and Dimensionality effects – Conduction electrons and Dimensionality – Number of atoms on the surface – Effects of small size : Physical and chemical properties - Electronic - structural - mechanical - optical and magnetic properties – applications.

Potential Wells – Quantum Confinement - Partial Confinement – 3D,2D,1D and 0D confinements - Quantum Wells , Wires and Dots – Properties dependent on Density of States.

UNIT 3: Experimental and Theoretical methods of verification of nano structures - Carbon Nanotubes – Synthesis, Properties and applications.

BOOKS FOR STUDY AND REFERENCE

1. CP Poole and FJ Owens, ***Introduction to Nanotechnology***, (2006) - A Wiley – Interscience publication.
2. Supriya Datta, ***Quantum Transport***, (2005) - Cambridge University Press.
3. Guozhong Cao, ***Nanostructures and Nanomaterials Synthesis, Properties and Applications,*** (2006) - Imperial College Press.
4. Richard Booker and Earl Boysen, ***Nanotechnology,*** (2005), Wiley Publishing Inc. USA.
5. Pradeep T., ***Nano: The Essentials***, (2007), Tata McGraw-Hill Publishing Co.
6. Mick Wilson, et al ***Nanotechnology,*** (2005), Overseas Press, New Delhi.
7. Rita John *(Edited)* ***Condensed Matter Theory,*** *Edited by*, UGC Academic Staff College, University of Madras, 2010.
8. Rita John, ***Solid State Physics,*** Tata Mc Graw Hill Publications, 2014.

GENERAL RELATIVISTY AND COSMOLOGY

TPPHY E306

No. of credits: 3

UNIT 1: **TENSORS**: Tensors in index notation - Kronecker and Levi Civita tensors - inner and outer products - contraction - symmetric and antisymmetric tensors - quotient law - metric tensors - covariant and contravariant tensors - vectors - the tangent space - dual vectors - tensors - tensor products - the Levi-Civita tensor - tensors in Riemann spaces - Vector-fields, tensor-fields, transformation of tensors - gradient and Laplace operator in general coordinates - covariant derivatives and Christoffel connection - Elasticity: Field tensor - field energy tensor - strain tensor - tensor of elasticity- curvature tensor

UNIT 2: **GENERAL RELATIVITY:** The spacetime interval - the metric - Lorentz transformations - spacetime diagrams - worldlines - proper time - energy-momentum vector - energy-momentum tensor - perfect fluids - energy-momentum conservation - parallel transport - the parallel propagator - geodesics - affine parameters - the Riemann curvature tensor - symmetries of the Riemann tensor - the Bianchi identity - Ricci and Einstein tensors - Weyl tensor - Killing vectors - the Principle of Equivalence - gravitational redshift - gravitation as spacetime curvature - the Newtonian limit - physics in curved spacetime - Einstein's equations - the Weak Energy Condition - causality - spherical symmetry - the Schwarzschild metric - perihelion precession

UNIT 3: **COSMOLOGY:** Expansion of the Universe - thermal history - and the standard cosmological model - Friedmann - Robertson-Walker type models of the Universe - Primordial inflation and the theory of cosmological fluctuations - Theory and observations of the cosmic microwave background and of the large-scale structure of the Universe - Dark matter and dark energy - theoretical questions and observational evidence - inflation - origin of galaxies and other open problems

BOOKS FOR STUDY AND REFERENCE

1. M. R. Spiegel***, Vector Analysis, Schaum'a outline series***, McGraw Hill, New York, 1974.
2. James Hartle, ***Gravity: An introduction to Einstein's general relativity,*** San Francisco, Addison-Wesley, 2002
3. Sean Carroll***, Spacetime and Geometry: An Introduction to General Relativity***, (Addison-Wesley, 2004).
4. Jerzy Plebanski and Andrzej Krasinski, ***An Introduction to General Relativity and Cosmology,*** Cambridge University Press 2006
5. Meisner, Thorne and Wheeler: ***Gravitation*** W. H. Freeman & Co., San Francisco 1973
6. Schutz: ***A First Course in General Relativity***.
7. J V. Narlikar, ***General relativity and cosmology,*** The Macmillan Company of India Ltd., 1978
8. Robert M Wald, ***General Relativity,*** Univ. of Chicago Press. (1984)
9. Robert M. Wald: ***Space, Time, and Gravity: the Theory of the Big Bang and Black Holes***, Univ. of Chicago Press.

10. J. V. Narlikar, ***Introduction to Cosmology,*** Jones & Bartlett 1983
11. Steven Weinberg, ***Gravitation and Cosmology,*** New York, Wiley, 1972.
12. Jerzy Plebanski and Andrzej Krasinski, ***An Introduction to General Relativity and Cosmology,*** Cambridge University Press 2006
13. R Adler, M Bazin& M Schiffer, ***Introduction to General Relativity***
14. A K Raichoudhury, ***Theoretical Cosmology***
15. A Papapetrou, ***Lectures in General Relativity***

ELEMENTS OF SPECTROSCOPY

TPPHY C313

No. of credits: 4

UNIT 1: **INTRODUCTION:** The Electromagnetic Spectrum - Absorption and Emission of Radiation – Width, Shape and intensity of Spectral Transitions – Absorbance - Mathematical Methods.

Atomic Spectroscopy**:** Observed Line Spectra - The Vector Model of the atom - Selection Rules and Energy Level Diagrams - LS & JJ Coupling -Paschen–Back Effect- Zeeman Effect and Stark Effects - Hyperfine Structure

UNIT 2: **MICROWAVE SPECTROSCOPY:** Rotation of Molecules – Rigid Rotor (Diatomic Molecules) – Expression for the Rotational Constant - Intensity of Spectral Lines – Effect of Isotopic Substitution - Molecular Parameters (Bond Length, Bond Angle, Dipole Moment) from Rotation Spectra – Techniques and Instrumentation.

UNIT 3: **INFRA-RED SPECTROSCOPY:** Vibrating Diatomic Molecules – Simple Harmonic Oscillator – Anharmonic Oscillator – Diatomic Vibrating Rotator – O,P,Q,R,S Branches – Vibration –Rotation Spectrum of Carbon Monoxide – Breakdown of the Born–Oppenheimer Approximation- Vibration of Polyatomic Molecules (Fundamental Vibration and symmetry and Overtones and combination bands) – Interpretation of IR Spectra of Organic Molecules (Characteristic Group Frequencies of Organic Molecule) - IR Spectrophotometer Instrumentation (Double Beam Spectrometer) – Fourier Transform Infrared Spectroscopy – Interferometer Arrangement - Applications.

***Raman Spectroscopy* :** Theory of Raman Scattering - Classical Theory and Quantum theory of Raman effect – Pure Rotational Raman Spectra - Vibrational Raman Spectra – Mutual Exclusion Principle - Structure Determination from Raman and Infra-Red Spectroscopy - Raman Spectrometer(Instrumentation) - Applications.

UNIT 4: **NUCLEAR MAGNETIC RESONANCE (NMR):** magnetic Properties of Nuclei – Resonance Condition – NMR Instrumentation – Relaxation Processes - Bloch equations – Chemical Shift – Indirect Spin -Spin Interaction – interpretation *of* simple organic molecules.

Electron Spin Resonance: Basic principle – ESR spectrometer – Total Hamiltonian (Direct Dipole-Dipole interaction and Fermi Contact Interaction) – Hyperfine Structure (Hydrogen atom) – ESR Spectra of Free radicals – Anisotropic Systems– Anisotropy of g-factors – Instrumentation.

UNIT 5: **LASERS:** Interaction of Matter with Radiation – Einstein Coefficients – Einstein's Theory of Transition Probabilities – Spontaneous and Stimulated Emissions – Optical Pumping – Population Inversion – Coherence –CO_2 *and He -Ne* Lasers – Laser as Raman Source – Ammonia Maser.

BOOKS FOR STUDY AND REFERENCE

1. C N Banwell and E M McCash, ***Fundamentals of Molecular Spectroscopy,*** 4th Edition, Tata McGraw–Hill, New Delhi, 1994.
2. G Aruldhas, ***Molecular Structure and Molecular Spectroscopy,*** Prentice–Hall of India, New Delhi, 1994.
3. J L McHale, ***Molecular Spectroscopy***, Pearson Education India, New Delhi, 2008.
4. J M Hollas, ***Basic Atomic and Molecular Spectroscopy,*** Royal Society of Chemistry, *RSC*, Cambridge, 2002.
5. B. P. Straughan and S. Walker, ***Spectroscopy Vol.I.,*** Chapman and Hall, New York, 1976.
6. R. P. Feynman et al. ***The Feynman Lectures on Physics Vol. III.,*** Narosa, New Delhi, 1989.

A. K. Chandra, ***Introductory Quantum Chemistry***, Tata McGraw Hill, New Delhi, 1989.

THEORY OF NANO SOLIDS

TPPHY E307

No. of credits: 3

UNIT 1: **QUANTUM CONFINED SYSTEMS:** Idealized quantum wells, wires and dots - size and dimensionality effects - Delocalization and confinement- dimensionalities of quantum nano structures - conduction electrons and dimensionality – Electronic structure from bulk to quantum dots - Fermi gas and density of states (DOS) – DOS in quantum confined systems - Bloch oscillations - Potential wells - Partial confinement – disorder in quantum confined systems – Properties dependent on Density of states.

APPLICATIONS: Infrared detectors - Quantum dot lasers - confinement in disordered and amorphous systems.

UNIT 2: **QUASIPARTICLES AND EXCITONS:** Introduction to excitons - Theory of bulk excitons - excitons in quantum wells - exciton binding energy - Excitons in Semi - empirical approaches - excitons in nano crystals of direct gap semiconductors - electron states in indirect gap semiconductors – Hole states – Screening of the electron – hole interaction and configuration interaction- Multi excitons – charging effects - single particle tunneling through semiconductor quantum dots.

UNIT 3: **QUANTITATIVE TREATMENT OF QUASI-PARTICLES:**

(i) Computational techniques: K.P Method and envelope function approximation – Tight Binding and empirical pseudopotential methods – Density Functional Theory - Comparison between different methods
(ii) Numerical Calculations: Interpretation of results – Comparison with experiments.

BOOKS FOR STUDY AND REFERENCE

1. C. Delerue and M.Lannoo, ***Nanostructures - Theory and modeling***
2. David W. Snoke, ***Solid State Physics – Essential Concepts***
3. Frank J. Owens and Charles P.Poole Jr, ***The Physics and Chemistry of Nanosolids***
4. David S. Sholl and Janice A. Steckel, ***Density Functional Theory***
5. Rita John, Edited, ***Condensed Matter Theory***, UGC Academic Staff College, University of Madras, 2010.
6. Rita John, ***Solid State Physics,*** Tata Mc Graw Hill Publications, 2014.

ASTROPHYSICS & ADVANCED NUCLEAR THEORY

TPPHY E308

No. of credits: 3

UNIT 1: **STARS:** Apparent and absolute magntitudes; stellar luminosity; Hertzprug – Russel (HR) diagrams; binary stars – visual binaries, eclipsing binaries spectroscopic binaries; mass-luminosity relation; spectral sequence; stellar atmospheres, photoabsorptio cross section, Saha equation.

UNIT 2: **STELLAR STRUCTURE:** Equations of stellar structure, early stages in life of a star, source of stellar energy, P-P chain and the CNO cycle, red giant stars, white dwarfs, neutron stars, supernovae and black holes, thermodynamics of black holes.

UNIT 3: **QUARK MODEL**: SU(3) Symmetry; Quark model for hadrons; Need for color quantum number; Color confinement; Solution of Dirac equation in a spherical cavity; MIT bag model

UNIT 4: **GAUGE THEORIES & APPLICATIONS TO ELEMENTARY PARTICLE PHYSICS**: Classical fields, Lagrangians and field equations; Symmetries & Conservation laws; Global and local gauge (phase) invariances; Abelian and non-Abelian gauge invariances; QCD Lagrangian; Dynamics of Color; Running coupling Constants in QED and QCD; Asymptotic freedom in QCD; Elements of Electroweak theory.

BOOKS FOR STUDY AND REFERENCE

1. A E Roy & D Clarke, ***Astronomy : Structure of the Universe***
2. J V Narlikar, ***Structure of the Universe***
3. Donald H Perkins, ***Introduction to High Energy Physics***
4. R K Bhaduri, ***Models of the Nucleon***
5. IJR Aitchison & AJG Hey, ***Gauge Theory of Particle Physics***
6. T P Cheng & L F Li, ***Gauge Theory Elementary Particles***

ADVANCED TOPICS IN MATHEMATICAL PHYSICS

TPPHY E309

No. of credits: 3

UNIT 1: **DISCRETE GROUPS:** Definition of a group, subgroup, class, Lagrange's theorem, invariant subgroup, Homomorphism and isomorphism between two groups. Representation of a group, unitary representations, reducible and irreducible representations Schur's lemmas, orthogonality theorem, character table, reduction of Kronecker product of representations, criterion for irreducibility of a representation.

UNIT 2: **CONTINUOUS GROUPS:** Infinitesimal generators, Lie algebra; Rotation group, representations of the Lie algebra of the rotation group, representation of the rotation group, D-matrices and their basic properties. Addition of two angular momenta and C.G. coefficients, Wigner-Eckart theorem.

UNIT 3: **SPECIAL UNITARY GROUPS:** Definition of unitary, unimodular groups SU(2) and SU(3). Lie algebra of SU(2). Relation between SU(2) and rotation group. Lie algebra of SU(3)-Gellmann's matrices. Cartan form of the SU(3). Lie algebra, roots and root diagram for SU(3). Weights and their properties, weight diagrams for the irreducible representations 3.3*-, 6,6 8, 10 and 10 of SU(3). Direct product of two SU(3) representations, Young tableaux method of decomposition of products of IR's illustrations with the representations of dim<10. C.G.coefficients for 3 x 3* and 3 x 6 representations. SU(3) symmetry in elementary particle physics, quantum numbers of hadrons and SU(2) and SU(3) classification of hadrons.

UNIT 4: **TENSORS:** Cartesian vectors and tensors illustration with moment of inertia, conductivity, dielectric tensors. Four vector in special relativitity, vectors and tensors under Lorentz transformations, Illustration from physics. Vectors and tensors under general co-ordinate transformations, contravariant and covariant vectors and tensors, mixed tensors; tensor algebra, addition, subtraction, direct product of tensors, quotient theorem, symmetric and antisymmetric tensors.

UNIT 5: **TENSOR CALCULUS:** Parallel transport, covariant derivative, affine connection. Metric tensor. Expression for Christoffel symbols in terms of and its derivatives (assuming D g = 0. Curvature tensor, Ricci tensor and Einstein tensor. Bianchi identities, Schwarzschild solution to the Einstein equation G=0

BOOKS FOR STUDY

1. A.W.Joshi, ***Group Theory for Physicists***
2. D.B.Lichtenberg, ***Unitary Symmetry and Elementary Particles***
3. E.Butkov, ***Mathematical Physics***
4. J.V.Narlikar, ***General Relativity & Cosmology***

BOOKS FOR REFERENCE

1. M.Hamermesh ***Group Theory***
2. M.E.Rose: Elementary Theory of Angular Momentum
3. Georgi : Lie Groups for Physicists
4. E.A.Lord: Tensors, Relativity & Cosmology

QUANTUM FIELD THEORY

TPPHY E 310

No. of credits: 3

UNIT 1: **CLASSICAL FIELDS**: Lagrangian & Hamiltonian Formulations; Variational Principle; Euler-Lagrange equations; Noether's theorem & Conservation Laws; Lorentz transformations and Conservation of Energy-momentumand angular momentum tensor; Internal symmetries and associated conservation laws

UNIT 2: **QUANTIZATION OF RELATIVISTIC FREE FIELDS**: Quantization of scalar, Dirac and electromagnetic fields; Number operator; States; Invariant Green's functions

UNIT 3: **INTERACTION QUANTUM FIELDS & PERTURBATION THEORY**: Interaction Picture; Time Evolution Operator; Covariant Pertubation theory; Normal product; Time ordered product & Wick's theorem; Invariant amplitude and Feynman rules; Scattering cross section; Spinor Electrodynamics and applications; Basic ideas on renormalization.

BOOKS FOR STUDY AND REFERENCE

1. David Lurie, ***Quantum Field Theory***
2. J D Bjorken & S Drell, ***Relativistic Quantum Mechanics***
3. J D Bjorken & S Drell, ***Relativistic Quantum Fields***
4. T D Lee, ***Particle Physics & Introduction to Field Theory***

BAND GAP ENGINEERING IN SEMICONDUCTORS

TPPHY E311

No. of credits: 3

UNIT 1: **BAND STRUCTURE OF SEMICONDUCTORS:** Direct, Indirect and Pseudo direct band gap semiconductors - Nature of band gaps from absorption curves - Concentration of charge carriers - Temperature dependence of n - Electron - hole pair generation and recombination: band to band (direct and indirect band gap transitions) and intra band (impurity related) transitions, free - carrier and phonon transitions.

UNIT 2: **MOBILITY AND CONDUCTIVITY IN SEMICONDUCTORS:** Influence of temperature on mobility- Recombination of electron hole pair- Electrical conductivity in semiconductors.

Excitons: Origin, electronic levels and properties, Radiative and non radiative recombination (Shockley - Read - Hall and Auger) processes.

Carrier transport - continuity equations.

Optical constants: Kramers - Kronig relations

UNIT 3: **BAND GAP ENGINEERING**: structural effects – chemical potential – crystal field – impact on degenerate states – band gap and alloying - Strain-induced band-gap engineering- Engineering band gaps in Ternary : Chalcopyrite and pnictides , Pseudo Direct, Quaternary, Magnetic and Oxide Semiconductors - Layered Semiconductors - Organic semiconductors.

UNIT 4: **SEMICONDUCTORS IN REDUCED DIMENSION:** Carbon materials - Bonding in graphene – Hopping mechanism – Hamiltonian of two dimensional solid (massless Dirac Hamiltonian): Tight binding Hamiltonian which includes π and σ bands. - Dirac points, degeneracy at K point, Linear dispersion, a Controlling of band gap, spatial inversion, time reversal symmetries, saddle point singularity, Density of States. Tuning of band gap in graphene – Effect of twisted layers – Applications in opto-electronics, bio-medicine, energy storage and generation.

Band gap engineering in graphene, quantum well, quantum wire and quantum dots. Semiconductors in electronics, spintronics and valleytronics – comprehensive comparison.

UNIT 5: **DFT RESULTS OF SEMICONDUCTORS:** Density Functional Theory (DFT) - an overview

Kohn-Hohenberg theorems - Kohn-Sham equation - exchange correlation potentials in semiconductors – Band structure as a tool in engineering band gaps.

BOOK FOR STUDY AND REFERENCE

1. C. Kittel, ***Introduction to Solid State Physics***, 7th Ed, Wiley, 2010.
2. Ben G. Streetman, ***Solid State Electronic Devices***, 3rd Ed., Prentice –Hall of India Private Limited, 1994
3. M. Ali Omar, ***Elementary Solid State Physics: Principles and Applications***, Addison-Wesley, 2000
4. S.M.Sze, ***Physics of semicondcutors Devices,*** New York: John Wiley, 1969.
5. Rita John, ***Solid State Physics,*** Tata Mc Graw Hill Publications, 2014.
6. Alexander O. E. Animalu, ***Intermediate Quantum Theory of Crystalline solids,*** Prentice Hall of India, New Delhi, 1978.
7. Eleftherios N. Economou, ***The Physics of Solids – Essentials and Beyond,*** Springer, 2010.
8. Rita John, Edited, ***Condensed Matter Theory***, UGC Academic Staff College, University of Madras, 2010.
9. A. Rycerz, J. Tworzydło and C. W. J. Beenakker, ***Valley filter and valley valve in graphene***, Nature Physics 3, 172 - 175 (2007).
10. Dimitrie Culcer, A. L. Saraiva, Belita Koiller, Xuedong Hu, and S. Das Sarma, ***Valley-Based Noise-Resistant Quantum Computation Using Si Quantum Dots,*** Phys. Rev. Lett. 108, 126804 (2012).
11. Niklas Rohling and Guido Burkard, ***Universal quantum computing with spin and valley states,*** New J. Phys. 14, 083008(2012).
12. E. A. Laird, F. Pei & L. P. Kouwenhoven, ***A valley–spin qubit in a carbon nanotube,*** Nature Nanotechnology 8, 565–568 (2013).
13. Richard Martin, ***Electronic Structure, Basic Theory and Practical Methods,*** Cambridge University Press, 2004.

INTRODUCTION TO BOSE-EINSTEIN CONDENSATION (BEC), SUPERFLUIDITY AND SUPERCONDUCTIVITY

TPPHY E312

No. of Credits: 3

UNIT 1: **THE IDEAL BOSE GAS:** The Bose distribution function – density of states - transition temperature and condensate fraction – density profile and velocity distribution - thermodynamic properties of ideal Bose gas – condensed phase and normal phase - Specific heat close to Tc

UNIT 2: **THE WEAKLY INTERACTING BOSE GAS:** Coherent states - Bosonic quantum fields – off diagonal long ranged order - weakly interacting Bose gas in the zero temperature limit: the Gross-Pitaevskii equation - BEC in ultra-cold atomic gases. Microscopic theory of weakly interacting Bose gas: the Bogoliubov transformation – elementary excitations and quasiparticle spectrum.

UNIT 3: **SUPERFLUID HELIUM II**: Introduction - classical and quantum fluids – thermal de Broglie wavelength – Superfluid properties of Helium II – superflow property and fountain effect. Flow quantization and vortices.

UNIT 4: **MICROSCOPIC THEORY OF SUPERCONDUCTIVITY:** Introduction – basic properties of superconductors – the mean-field Hamiltonian - the BCS ground state – BCS excited states in the zero temperature limit – BCS theory at non-zero temperature.

BOOKS FOR STUDY

5. C. J. Pethick and H. Smith, ***Bose-Einstein Condensation in Dilute Gases,*** 2nd edition, Cambridge University Press, 2002.
6. G. Rickayzen, ***Theory of Superconductivity***, Wiley-Interscience publisher, 1965.

BOOKS FOR REFERENCE

1. Kerson Huang, ***Introduction to Statistical Physics***, 2nd edition, CRC press, 2001.
2. Lev P. Pitaevskii and S. Stringari, ***Bose–Einstein Condensation***, Clarendon Press, Oxford, 2003
3. J. R. Schrieffer, ***Theory of Superconductivity***, 1st edition, Perseus Books, 1971.

CRYSTAL GROWTH AND THIN FILM PHYSICS

TPPHY E313

No. of credits: 3

UNIT 1: **NUCLEATION AND GROWTH NUCLEATION**: Different kinds of nucleation - Concept of formation of critical nucleus – Classical theory of nucleation - Spherical and cylindrical nucleus - Growth Kinetics of Thin Films - Thin Film Structure – Crystal System and Symmetry.

UNIT 2: **GROWTH TECHNIQUES SOLUTION GROWTH TECHNIQUE**: Low temperature solution growth: Solution - Solubility and super solubility – Expression of super saturation – Miers T-C diagram - Constant temperature bath and crystallizer - Seed preparation and mounting - Slow cooling and solvent evaporation methods. Gel Growth Technique : Principle – Various types – Structure of gel – Importance of gel – Experimental procedure – Chemical reaction method – Single and double diffusion method – Chemical reduction method – Complex and decomplexion method – Advantages of gel method.

UNIT 3: **MELT AND VAPOUR GROWTH TECHNIQUES**: Melt technique: Bridgman technique - Basic process – Various crucibles design - Thermal consideration – Vertical Bridgman technique - Czochralski technique – Experimental arrangement – Growth process. Vapour technique: Physical vapour deposition – Chemical vapour deposition (CVD) – Chemical Vapour Transport.

UNIT 4: **THIN FILM DEPOSITION TECHNIQUES**: Thin Films – Introduction to Vacuum Technology - Deposition Techniques - Physical Methods – Resistive Heating, Electron Beam Gun, Laser Gun Evaporation and Flash Evaporations, Sputtering - Reactive Sputtering, Radio-Frequency Sputtering - Chemical Methods – Spray Pyrolysis – Preparation of Transparent Conducting Oxides.

UNIT 5: **CHARACTERIZATION TECHNIQUE:** X – Ray Diffraction (XRD) – Powder and single crystal - Fourier transform Infrared analysis (FT-IR) – Elemental analysis – Elemental dispersive X-ray analysis (EDAX) - Scanning Electron Microscopy (SEM) – UV-Vis-NIR Spectrometer – Etching (Chemical) – Vickers Micro hardness.

BOOKS FOR STUDY AND REFERENCE

1. J.C. Brice, ***Crystal Growth Processes***, John Wiley and Sons, New York (1986)
2. P. SanthanaRagavan and P. Ramasamy, ***Crystal Growth Processes and Methods***, KRU Publications,
3. Kumbakonam (2001)

A. Goswami, ***Thin Film Fundamentals,*** New Age International (P) Limited, New Delhi (1996)

4. B.R.Pamplin , ***Crystal Growth,*** Pergamon press, London (1975).
5. P.M.Dryburgh, B.Cockayane and K.G.Barraclough, ***Advance Crystal Growth*** –Prentice – Hall, London, 1986.